Cost Analysis of Ongoing Care of Patients With End-Stage Renal Disease: What are the Important Determinants?

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Purpose

Care of patients with end-stage renal disease is resource intense but also important, since it is life saving. Hemodialysis and peritoneal dialysis can be used as renal replacement therapy when transplantation is not appropriate or available. When considering hemodialysis, patients can be treated with in-hospital, out of hospital ("satellite"), home or self-care hemodialysis. Treatment of patients with home / self-care hemodialysis or peritoneal dialysis is called "self-care dialysis", due to a lower requirement for nursing resources. There is a large proportion of patients starting dialysis who could be successfully treated with any of these modalities, including "self-care dialysis". The objective of our study was to describe the costs and resources required to treat patients with end-stage renal disease.

Approach

Patients living in Calgary on dialysis treatment for more than six months were asked to participate. Costs considered included those related to outpatient dialysis care, inpatient care, outpatient non-dialysis care, and physician claims.

Key findings

The following are the key findings:

- In July 1999, 416 patients were treated in Calgary with dialysis (266 in-hospital hemodialysis, 55 out of hospital hemodialysis, 79 peritoneal dialysis, 13 home hemodialysis, and 3 self care hemodialysis).
- Patients treated with in-hospital and out-of-hospital hemodialysis were older than those treated with home / self-care hemodialysis and peritoneal dialysis. Patients treated with home / self-care hemodialysis or peritoneal dialysis were more likely to be working than those patients treated with in- or out-of-hospital hemodialysis. Patients on home/self-care hemodialysis had less other diseases than patients treated with the other modalities.
- The adjusted one-year cost for in-hospital, out-of-hospital, home / self-care hemodialysis and peritoneal dialysis was $74,800, $62,103, $45,239, and $37,129 respectively. There was a greater requirement for nursing time for patients treated with in- or out-of-hospital hemodialysis and greater use of supplies in patients treated with peritoneal dialysis. For these study patients, the cost of care was predicted only by the dialysis modality and the presence of other diseases.

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Conclusions

In-hospital hemodialysis was the most expensive costing nearly $75,000 per patient per year. "Self-care dialysis" (i.e. home / self-care hemodialysis and peritoneal dialysis) cost on average $30,000 less. A small proportion of the difference in cost was due to a difference in the hospital overhead. In general, though, the cost difference was due to lower use of "real" expenses such as a lower requirement for nursing care, laundry, housekeeping, portering, and electricity by home / self-care hemodialysis and peritoneal dialysis patients. Previous work has shown no significant difference in survival or health related quality of life between patients treated with hemodialysis or peritoneal dialysis. As such, it appears appropriate to simply compare the costs among the renal replacement therapies to determine which modality is most efficient. Since "self-care dialysis" was least costly and also used less of the most scarce local resource (nursing time), we believe that for people who are awaiting or are not eligible for a renal transplant, health care resources can be used most efficiently by encouraging treatment with either home / self-care hemodialysis or peritoneal dialysis.

For more information

Copies of the report are available from the
Alberta Centre for Health Services Utilization Research

- by contacting David Johnson by e-mail at cujecjohnson@shaw.ca
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Alberta Centre for Health Services Utilization Research

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SUMMARY

Care of patients with end-stage renal disease is important and resource intense. To enable end-stage renal disease programs to develop strategies for more cost efficient care, an accurate estimate of the cost of caring for end-stage renal disease patients is needed. The objective of our study was to develop an updated and accurate itemized description of the costs and resources required to treat end-stage renal disease patients using dialysis and to contrast the differences in resources required for the various dialysis modalities. Patients who had been on treatment with any of the dialysis modalities for more than six months and agreed to enrollment were followed prospectively for one year. Information on baseline patient characteristics, including comorbidity, was collected. Costs considered included those related to outpatient dialysis care, inpatient care, outpatient non-dialysis care, and physician claims. We also estimated separately the cost of maintaining the dialysis access. Of the one hundred and sixty-six patients who were enrolled, eighty-eight were treated with in-center hemodialysis, thirty-one with satellite hemodialysis, nine with home/self-care hemodialysis and thirty-eight with peritoneal dialysis. Overall cost of care per year for in-center, satellite, home/self-care hemodialysis and peritoneal dialysis were $74,316 (95% CI 69,137, 79,495), $60,983 (95% CI 57,308, 64,658), $44,143 (95% CI 31,394, 56,892), and $43,193 (95% CI 37,723, 48,663) respectively ($p < 0.001$). After adjustment for the effect of other important predictors of cost such as age and comorbidity, the difference in cost between the modalities persisted. Hemodialysis patients treated with synthetic grafts, central venous catheters and native arteriovenous fistulas incurred mean annual *access-related costs* of $4,850, $3,177 and $509, respectively ($p < 0.001$). To maximize the efficiency with which care is provided to end-stage renal disease patients, programs should encourage the use of home/self-care hemodialysis and peritoneal dialysis.

INTRODUCTION

Care of patients with end-stage renal disease is resource intense but also important, since renal replacement therapy is life saving. It has been estimated that two to three percent of a developed country's health care budget is spent caring for patients with end-stage renal disease, despite the fact that only 0.07 percent of the population suffers from end-stage renal disease [1-4]. Due to high costs and the increasing prevalence of end-stage renal disease [1-5], it is important for end-stage renal disease programs to develop strategies for more efficient care. In this regard, it should be noted that the largest area of cost for end-stage renal disease programs relates to the provision of outpatient renal replacement therapy [6].

There are different methods of renal replacement therapy, including renal transplantation, hemodialysis and peritoneal dialysis. When determining which modality to encourage, it is important to consider the effect of each modality on mortality, health-related quality of life and resource use. Renal transplantation is associated with superior clinical outcomes, health-related quality of life and cost savings compared with dialysis [7, 8]. Unfortunately, many patients are not candidates for renal transplantation, and, for those who are eligible, the waiting time on dialysis may be several years [1]. Although controversial, survival appears to be comparable between peritoneal dialysis and hemodialysis [9-12]. Studies suggest that health-related quality of life is similar for patients on in-center hemodialysis and peritoneal dialysis [13]; patients treated with home/self-care hemodialysis may have a slightly higher health-related quality of life [14, 15].

Some patients may have a preference for one modality, based either on medical or social factors. However, there is a large proportion of patients starting dialysis who could be successfully treated with any of the dialytic modalities [16-18]. For this group of patients, who may have limited knowledge about kidney failure and its treatment, it is important for nephrologists and end-stage renal disease programs to educate patients about which modality would be optimal for them, keeping in mind the overall resources of the program. To facilitate this, end-stage renal disease programs require a detailed description of the cost (and requirement for important resources, such as nursing time) of the different dialytic modalities.

Previous cost studies are largely outdated [19-22], have used aggregate costs or "prices" [23], have been performed outside of North America where practice patterns may be different [24, 25], or have studied dialytic modalities (intermittent peritoneal dialysis) not in use today [6]. In our study, we sought to inform end-stage renal disease programs by providing an updated and

accurate itemized list of the costs and resources required to treat patients with end-stage renal disease using dialysis and to contrast the differences in resources required for the various dialysis modalities. To achieve this, we prospectively enrolled patients who had been treated with any of the dialysis modalities for more than six months to enable us to estimate the cost of ongoing treatment of patients with in-center, satellite, home/self-care hemodialysis or peritoneal dialysis.

METHODS

Setting:

The Conjoint Medical and Research Ethics Board at the University of Calgary approved the study protocol. In July 1999, 416 patients were treated locally with dialysis (266 in-center hemodialysis, 55 satellite hemodialysis, 79 peritoneal dialysis, 13 home hemodialysis, and 3 self care hemodialysis). More than three hundred of these patients had been on dialysis for more than six months and were eligible for enrollment. Six months was chosen for these two reasons:

1) by six month's time, the dialysis modality and a permanent vascular access have generally been established, and
2) the goal of this study was to determine the cost of ongoing dialysis, rather than the costs associated with initiating dialysis.

Patients were approached for enrollment in consecutive fashion from a randomly generated list of those being treated with each modality.

Within the Southern Alberta Renal Program, which cares for all patients with end-stage renal disease in Calgary, hemodialysis patients receive at least four hours of dialysis three times per week, using synthetic dialysers aiming for a goal Kt/V of $\geq$ 1.3. Twenty percent of patients receive treatment with high-flux dialysers; no hemodialyser reuse occurs. Dialysis machines are COBE Centrysystem 3 (COBE Laboratories, Lakewood, Colorado). In 1999, there were forty-five hemodialysis stations for in-center hemodialysis located in a tertiary hospital, ten stations for satellite hemodialysis (located outside the hospital), three stations for self-care hemodialysis, and two stations for home hemodialysis training. Patients on self-care hemodialysis operate independently of nurses. The training period for home and self-care hemodialysis is similar (six weeks of supervision and training while on dialysis). Among all hemodialysis patients in the Southern Alberta Renal Program, eighteen percent have a permanent catheter (placed by interventional radiologists), twenty-nine percent have a synthetic graft and fifty-three percent have native arteriovenous fistulas.

Patients on peritoneal dialysis receive either continuous ambulatory peritoneal dialysis (usually starting with four 2.5 litre exchanges per day) or cyclic peritoneal dialysis. All patients receive a one-week training period prior to the initiation of therapy. Treatment of peritoneal dialysis patients is individualized: the goal total Kt/V (renal and peritoneal clearance) is ≥ 2.1 [26] and the majority of patients are treated with dextrose-based solutions. A minority of patients receives a daily exchange with nutrineal™ (Baxter) or extraneal™ (Baxter). The goal hemoglobin locally for both hemodialysis and peritoneal dialysis patients was 120 g/l.

Data Collection:

Demographic information such as age, gender, marital and employment status, income and education level, and living arrangements were assessed by way of a self-administered questionnaire. The cause of renal failure was recorded as per the attending physicians' assessment. The presence of comorbid illness was assessed by a trained research nurse as of the enrollment date by complete review of the patients' inpatient and outpatient record (containing all information pertaining to medical and surgical consultations and all previous hospital admissions) and by direct patient interview by a trained nursing research assistant. Information was collected for the 19 variables that constitute the Charlson Comorbidity Index [27], which has been validated for use in patients with end-stage renal disease [28]; patients were categorized as low-risk (Charlson score smaller or equal to three), medium risk (Charlson score equal to four to five) and high-risk (Charlson score greater or equal to six) [28].

Data on the number of clinic visits, medication use (including the doses of erythropoietin and intravenous iron), allocated nursing time for outpatient dialysis runs, and use of laboratory testing was determined for all participants from the Southern Alberta Renal Program computerized database [29].

Measuring Costs:

This study took the perspective of the health care purchaser and included only direct health care related costs. Societal costs (i.e. time costs or patient transport costs) were excluded. All costs are valued in 2000 Canadian dollars (1 CAN $ = 0.66 US $ = 0.47 British £). Costs were organized into four main categories: outpatient dialysis expenses, inpatient expenses, outpatient non-dialysis expenses, and physician fees.

Outpatient Dialysis Expense

Outpatient dialysis comprises the largest portion of end-stage renal disease costs. It included equipment costs, staff, consumable items and reverse osmosis water. The cost of the dialysis machine per run was determined as follows. Since one hundred and eighty hemodialysis machines were required locally and provided 64,000 runs in 1999, a conservative estimate of the fixed cost per run was $10.72 assuming that:

i) an annuity factor of 7.3601 was used,
ii) machines were amortized over ten years with no resale value, and
iii) maintenance costs for equipment (based on actual maintenance performed in 1999) were $3.08 per run.

Staff costs included direct and indirect nursing costs, as well as the cost of other support staff such as social workers, dietitians and clerical staff. Direct nursing costs were estimated for each patient for every dialysis session based on a recorded workload measurement unit. Indirect nursing costs (i.e. nursing administration) were divided equally among patients. As per standard Calgary Health Region costing procedures, we used thirty percent overhead for in-center hemodialysis, twenty-five percent for satellite and self-care hemodialysis, and twenty percent for home hemodialysis and peritoneal dialysis.

The cost of consumable items such as needles, bloodlines and hemodialysers for hemodialysis was based on average usage (as recorded in the monthly dialysis supplies records). Since reverse osmosis water was purchased on a contract basis, we included the price of water required to reconstitute dialysate per patient.

Inpatient Expenses

Information on all hospital admissions (whether the admission was for kidney failure-related or unrelated reasons), including the cost, was acquired from the Calgary Health Region corporate database. Resource use was broken down into seven categories: nursing, laboratory, diagnostic, surgical, surgical supplies, medications and support staff. Inpatient costing was calculated using provincially approved methodology in accordance with the Provincial and National Management Information Systems guidelines [30, 31]. Resource use (i.e. number of medications, lab tests or consumables used; nursing care hours allocated per patient based on a recorded workload measurement unit) was measured for all patients [29]. The number of units used by each patient was then multiplied by the cost per unit, which is estimated annually in the Calgary Health Region, to give an estimate of the direct costs. Direct costs were then combined with an estimate of indirect costs (defined as those costs not directly associated with patient care, i.e. cost of nursing managers, administration, etc) for every inpatient encounter.

The quality of the data reporting of costs in Alberta has been highly ranked by the Canadian Institutes for Health Information [32]. Due to the limited number of patients treated with cyclic peritoneal dialysis, patients treated with continuous ambulatory peritoneal dialysis and cyclic peritoneal dialysis were pooled together to give a more stable estimate of inpatient costs. Inpatient costs were excluded from all other cost categories to avoid double counting.

Outpatient Non-Dialysis Expenses

Outpatient non-dialysis expenses included clinic visits, emergency room, day surgery, labs, radiology and medications. The cost of outpatient care was determined by examining actual patient resource consumption and allocated nursing contact for patients treated with in-center, satellite, home/self-care hemodialysis and peritoneal dialysis.

The Southern Alberta Renal Program database [29] records the number of clinic visits made by each patient; cost per visit was determined by dividing the annual clinic staff's wages (including the wages of clinic nurses, reception staff and nursing managers) by the total number of clinic visits annually for all patients, and adding a twenty percent overhead charge. The number of outpatient visits to the emergency room, day surgery unit and radiology was determined from the Calgary Health Region corporate database. The cost for each visit (including indirect costs and twenty percent overhead) was estimated based on the average cost for a representative sample of Calgary Health Region patients who visited the emergency room (categorized by reason for assessment) or received treatment in day surgery or radiology (categorized by procedure).

The frequency with which lab tests were performed was recorded for each patient by the Southern Alberta Renal Program database [29]. This frequency was multiplied by the unit costs assigned to each laboratory test based on a defined workload measurement unit.

Medications were divided into three categories: erythropoietin (Eprex™; Ortho Biotech); intravenous iron (Venofer™, American Regent Laboratories, Inc); and others. Frequency and dosage was extracted from the SARP database for each patient [29]. For Eprex™ and Venofer™, we multiplied the dosage by the unit costs ($18.45 per one thousand units for Eprex™ and $30.00 per one hundred milligrams for Venofer™) to determine the cost per patient. All other medication costs were determined from the Alberta Pharmaceutical Price List, summed to give a total cost per patient.

Physician Fees

To maintain patient confidentiality, physician claims were acquired from Alberta Health and Wellness in aggregate groups of six to ten patients, according to dialysis modality and comorbidity. Physician claims included visits to general practitioner, nephrologist, radiologist, and other subspecialists.

Costs Related to the Dialysis Access

For hemodialysis patients, we assessed the cost of maintaining the vascular access for patients who were treated at the start of the study period with a permanent catheter, a synthetic graft or a native arteriovenous fistula. Costs considered included any interventional radiology (i.e. line placement, fistulograms, access angioplasty), day surgery for declotting and creation of new access, or hospital admission for access-related problems (defined as line sepsis, or admission for an access-related surgical complication) which occurred during the twelve-month observation period for all patients.

STATISTICAL ANALYSIS

The primary study hypothesis was that the total cost of care for patients treated with in-center, satellite, home/self-care hemodialysis or peritoneal dialysis would be equivalent, after controlling for other important variables. Descriptive statistics used were the arithmetic mean and ninety-five percent confidence intervals (95% CI) for normally distributed samples and median (with interquartile ranges) for skewed variables. The Charlson index was calculated using the original formulae and weights [27]. Two sample two-sided t-tests or one-way ANOVA were used to test for differences in continuous variables between two or more groups, respectively. Chi-square was used to test for differences in discrete variables. The Kruskal-Wallis test was used to compare for differences between the cost of maintaining the different vascular accesses used in hemodialysis, since these variables were not normally distributed.

Multiple linear regression was performed for the total cost of care using the following predictor variables: age, sex, need for assisted living, work status, education, Charlson comorbidity score and the dialysis modality. Manual backward stepwise elimination of the least significant variable was done based on a combination of clinical and statistical importance. Interaction and confounding was assessed for and normal plots of the residuals of the regression models were examined to test for constant variance. All analyses were done with STATA (Stata Corporation, College Station, Texas). We computed 'adjusted costs' for average hypothetical patients treated with the

various dialysis modalities (adjusted for the above predictor variables) using the least squares means method.

RESULTS

Patients

Of the three hundred and thirty-two patients who were eligible for the study, one hundred and sixty-six were enrolled. Eighty-eight of them were treated with in-center hemodialysis, thirty-one with satellite hemodialysis, nine with home/self-care hemodialysis and thirty-eight with peritoneal dialysis (thirty-two with continuous ambulatory peritoneal dialysis and six with cyclic peritoneal dialysis. One hundred and ten patients were not approached due to the inability to speak English or because of an inability to contact them after repeated attempts, and fifty-six patients did not wish to participate. Non-enrolled patients were similar in sex (55.6 percent male) but tended to be older (mean age 63.8 years) and were less likely to be on peritoneal dialysis (16.4 percent of non-enrolled patients were on peritoneal dialysis).

Patients treated with in-center hemodialysis and satellite hemodialysis were older than those treated with home/self-care hemodialysis and peritoneal dialysis (Table 1). Patients treated with home/self-care hemodialysis or peritoneal dialysis were more likely to be working than those patients treated with in-center or satellite hemodialysis ($p = 0.08$ by Chi-square). However, income and the need for assisted living appeared similar among the patients treated with the various dialysis modalities (Table 1). Patients on home/self-care hemodialysis had less comorbid disease than patients treated with the other modalities, as reflected by the lower Charlson Comorbidity Scores. For hemodialysis patients, the vascular access was a temporary catheter in 3.9 percent, a permanent catheter in 11.7 percent, a synthetic graft in 28.1 percent and a native arteriovenous fistula in 56.3 percent.

Costs

We were able to assess costs for the full twelve-month observation period for one hundred and twenty-eight of the one hundred and sixty-six patients. Of the remainder, sixteen died and nine received a renal transplant during the subsequent year, and thirteen patients were enrolled after the start of the fixed costing period. Since we wanted to establish an accurate cost of treating a patient on dialysis, for these patients, only a portion of the twelve-month period was costed. Annual costs of treatment on each

modality were then determined by direct extrapolation from this truncated costing period.

The direct health care costs for patients treated with each of the dialysis modalities are shown in Table 2. Overall cost of care per year for in-center, satellite, home/self-care hemodialysis and peritoneal dialysis were $74,316 (95 % CI 69,137, 79,495), $60,983 (95 % CI 57,308, 64,658), $44,143 (95 % CI 31,394, 56,892), and $43,193 (95 % CI 37,723, 48,663) respectively ($p < 0.001$). After adjusting the cost for the effect of age, sex, need for assisted living, work status, education, and Charlson comorbidity score, the 'adjusted cost' for treating average hypothetical patients with in-center, satellite, home/self-care hemodialysis and peritoneal dialysis was $74,800, $62,103, $45,239, and $37,129, respectively (where $p < 0.001$).

Table 3 presents a detailed breakdown of outpatient dialysis expenses, which comprised the largest portion of total costs. The major difference among the different modalities was the requirement for supplies, consumables and nursing staff. There was a greater requirement for nursing time for patients treated with in-center and satellite hemodialysis and greater use of supplies in patients treated with peritoneal dialysis. Overall, outpatient dialysis costs were highest for in-center and satellite hemodialysis.

For access-related costs (Table 4), patients treated with a synthetic graft at the beginning of the costing period incurred the most access-related costs (mean $4,850 (median 3,499, 25-75 percentile 590-6,725)). Alternatively, patients who began the costing period with a functioning arteriovenous fistula had significantly lower access-related costs (mean $509 per patient year) ($p < 0.001$ by Kruskal-Wallis test). Since we were interested in the cost of maintaining the dialysis access, patients who began the study with a temporary catheter ($n = 5$) were excluded from this analysis.

Predictors of Cost

Using multiple linear regression with total cost as the dependent variable, we found only the Charlson Comorbidity Score and dialysis modality to be associated with health care costs ($p < 0.001$). Age, sex, need for assisted living, work and education status were not associated with annual costs ($p > 0.10$). For every increment in the Charlson Comorbidity Score by one, annual costs increased by $3,243 ($p < 0.001$). As one would not expect an equivalent increase in cost for each of the comorbidities that constitute the Charlson index, we also determined the effect of individual comorbid conditions on cost, while controlling for the effect of other important predictors. After controlling for the effect of these covariates, end-stage renal disease patients with diabetes had higher annual health care costs

($11,634, $p < 0.001$) (compared to non-diabetics) as did those with a history of congestive heart failure ($9,976, $p = 0.008$) (compared to those without a history of congestive heart failure).

DISCUSSION

Direct health care costs for end-stage renal disease patients varied substantially among patients treated with the different dialysis modalities. In-center hemodialysis was the most expensive renal replacement therapy, costing nearly $75,000 per patient year. Self-care dialysis (i.e. home/self-care hemodialysis and peritoneal dialysis) cost on average $20,000 less due to a lower requirement for nursing care for outpatient dialysis.

Our results, based on patients treated with contemporary dialysis modalities in 1999 in North America, are consistent with previous work, which showed that home hemodialysis and peritoneal dialysis were the least expensive treatment options [6, 15, 19, 24, 33]. This finding has now been reported in Europe [15, 24], New Zealand [25] and Canada [6], although it was not as clear from these studies whether cost-differences were due to the dialysis modalities or to differences in patient comorbidity between modalities. By controlling for the effect of patient comorbidity, our study shows that the lower cost of caring for patients treated with "self-care dialysis" was not due to a difference in patient comorbidity. This result is consistent with a study by Hirth et al [34] who showed that the presence of additional comorbid disease did not significantly increase outpatient hemodialysis costs. It is apparent from our study that most of the cost-savings associated with self-care dialysis was due to a reduction in the cost of outpatient dialysis (Table 2). These cost-savings are likely to be noted by other end-stage renal disease programs, irrespective of patient characteristics.

A small proportion of the difference in cost that we noted between in-center or satellite hemodialysis and "self-care dialysis" was due to a difference in the overhead considered for each modality (overhead being charged at a higher rate for in-center hemodialysis). In general, though, this is consistent with a lower use of "real" expenses such as laundry, housekeeping, portering, and electricity by home/self-care hemodialysis and peritoneal dialysis patients. Also, we did not consider any capital expenses (for building space) for the in-center, satellite or self-care hemodialysis programs since it is difficult to estimate the cost of space within a hospital. However, by amortizing the net present value of the building housing the dialysis unit within the hospital ($31,236,592) over forty years and considering the portion of the building used for in-center dialysis as well as the number of dialysis runs performed per year, we estimate the capital cost per in-center dialysis patient per year at $1,050 per year. This is more than

the $430 per patient per year capital cost for patients treated with satellite hemodialysis. In addition to the monetary value, though, it is important to consider the opportunity cost of using space within a hospital for outpatient care of dialysis patients. If space within hospitals is a limited resource, as it is locally, then encouraging treatment outside the hospital (through use of satellite hemodialysis, home hemodialysis and peritoneal dialysis) may be an important consideration, aside from monetary considerations.

Although the discrepancy in costs is important, it is also important to consider health outcomes associated with the different dialysis modalities. Previous work has shown no significant difference in survival [9-12] or health-related quality of life [13, 15] between patients treated with hemodialysis or peritoneal dialysis. Within hemodialysis, those patients treated with home/self-care hemodialysis may have a slightly higher health-related quality of life than those treated with in-center hemodialysis [15]. As such, it appears appropriate to simply compare the costs among the renal replacement therapies to determine which modality is most efficient. Since self-care dialysis was least costly and also used less of the most scarce local resource (nursing time), we believe that for people who are awaiting or are not eligible for a renal transplant, health care resources can be used most efficiently by encouraging treatment with either home/self-care hemodialysis or peritoneal dialysis.

For patients treated with hemodialysis, the cost of access-related care was significantly lower for those who began the study period with a functioning native arteriovenous fistula. For patients who are eligible for a native arteriovenous fistula, our study suggests that, in addition to extra clinical benefit in terms of longer access patency and lower risk of infection [35], there is the potential to realize substantial cost-savings by encouraging placement of a native arteriovenous fistula rather than a synthetic graft. It will be important for future studies to consider the cost of access-related care from the time of access placement to account for patients who experience primary access failure after arteriovenous fistula creation and subsequently require treatment with a permanent catheter or a synthetic graft. In general, though, our results strongly support existing guidelines promoting the use of a native arteriovenous fistula as the first-line vascular access in hemodialysis patients with end-stage renal disease [36].

This study had several limitations. We were only able to enroll fifty percent of eligible patients. We enrolled a limited number of peritoneal dialysis as well as home/self-care hemodialysis patients though this is reflective of the local distribution of patients among the modalities. In fact, we enrolled a higher percentage of eligible peritoneal dialysis (sixty percent) and home/self-care hemodialysis patients (sixty-four percent). It is possible that our results are affected by selection bias and that enrolled patients were

healthier than non-enrolled patients. If true, we may have underestimated costs, especially the cost of hospital admissions. For those patients that were enrolled, by using the Southern Alberta Renal Program database[29] to collect data on allocated nursing time for outpatient dialysis runs, use of laboratory testing, and medication use, our estimate of the costs of outpatient dialysis, Eprex™, Venofer™ and outpatient medications were very accurate.

It is also important to note that in Alberta, physician remuneration varies greatly between the different modalities, being highest for in-center and satellite dialysis. As such, physician cost per modality would need to be adjusted for regions where nephrologists are paid on a capitation basis. For this analysis, we excluded societal costs such as time costs and costs from work loss. If we had incorporated societal costs into our data, it is likely that the difference between the self-care modalities and in-center hemodialysis would have been even greater.

Due to the high cost of care and the increasing prevalence of end-stage renal disease, it is important for end-stage renal disease programs to develop strategies for more efficient care. While the costing estimates in this study have most relevance to Canadian centres, we feel that the general recommendation that can be made from our study (i.e. that self-care dialysis should be promoted for eligible patients) is of relevance to other health systems. Potentially, resources that are released by patients performing self-care dialysis (as opposed to in-center hemodialysis) could be used to enhance the care given to these same patients or to other local end-stage renal disease patients.

REFERENCES

1. Economic costs of ESRD, *American Journal of Kidney Diseases,* 36: S163-176, 2000

2. Garella, S., The costs of dialysis in the USA, *Nephrol Dial Transplant,* 12: 10-21, 1997

3. Mallick, N.P., The costs of renal services in Britain, *Nephrol Dial Transplant,* 12: 25-28, 1997

4. Tomson, C.R., Recent advances: nephrology, *British Medical Journal,* 320: 98-101, 2000

5. United States Renal Data System: Incidence and prevalence of ESRD, *American Journal of Kidney Diseases*, 30 (Suppl 1): S40-S53, 1997

6. Goeree, R., Manalich, J., Grootendorst, P., Beecroft, M.L., and Churchill, D.N., Cost analysis of dialysis treatments for end-stage renal disease (ESRD), *Clin Invest Med*, 18: 455-464, 1995

7. Wolfe, R.A., Ashby, V.B., Milford, E.L., Ojo, A.O., Ettenger, R.E., Agodoa, L.Y., Held, P.J., and Port, F.K., Comparison of mortality in all patients on dialysis, patients on dialysis awaiting transplantation, and recipients of a first cadaveric transplant, *N Engl J Med*, 341: 1725-1730, 1999

8. Laupacis, A., Keown, P., Pus, N., Krueger, H., Ferguson, B., Wong, C., and Muirhead, N., A study of the quality of life and cost-utility of renal transplantation, *Kidney Int*, 50: 235-242, 1996

9. Bloembergen, W.E., Port, F.K., Mauger, E.A., and Wolfe, R.A., A comparison of mortality between patients treated with hemodialysis and peritoneal dialysis, *J Am Soc Nephrol*, 6: 177-183, 1995

10. Collins, A.J., Hao, W., Xia, H., Ebben, J.P., Everson, S.E., Constantini, E.G., and Ma, J.Z., Mortality risks of peritoneal dialysis and hemodialysis, *Am J Kidney Dis*, 34: 1065-1074, 1999

11. Fenton, S.S., Schaubel, D.E., Desmeules, M., Morrison, H.I., Mao, Y., Copleston, P., Jeffery, J.R., and Kjellstrand, C.M., Hemodialysis versus peritoneal dialysis: a comparison of adjusted mortality rates, *Am J Kidney Dis*, 30: 334-342, 1997

12. Foley, R.N., Parfrey, P.S., Harnett, J.D., Kent, G.M., O'Dea, R., Murray, D.C., and Barre, P.E., Mode of dialysis therapy and mortality in end-stage renal disease, *J Am Soc Nephrol*, 9: 267-276, 1998

13. Merkus, M.P., Jager, K.J., Dekker, F.W., Boeschoten, E.W., Stevens, P., and Krediet, R.T., Quality of life in patients on chronic dialysis: self-assessment 3 months after the start of treatment, The Necosad Study Group, *Am J Kidney Dis*, 29: 584-592, 1997

14. Churchill, D.N., Torrance, G.W., Taylor, D.W., Barnes, C.C., Ludwin, D., Shimizu, A., and Smith, E.K., Measurement of quality of life in end-stage renal disease: the time trade-off approach, *Clin Invest Med*, 10: 14-20, 1987

15. de Wit, G.A., Ramsteijn, P.G., and de Charro, F.T., Economic evaluation of end-stage renal disease treatment, *Health Policy*, 44: 215-232, 1998

16. Guernsey, L., Self-care for the ESRD patient, *Nephrol Nurse*, 4: 8-12, 1982

17. Sexton Dobby, A., Self-care hemodialysis training and anatomy: The patient's perspective, *CANNT Journal*, Fall: 17-18, 1992

18. Prichard, S.S., Treatment modality selection in 150 consecutive patients starting ESRD therapy, *Perit Dial Int*, 16: 69-72, 1996

19. Churchill, D.N., Lemon, B.C., and Torrance, G.W., A cost-effectiveness analysis of continuous ambulatory peritoneal dialysis and hospital hemodialysis, *Med Decis Making*, 4: 489-500, 1984

20. Garner, T.I. and Dardis, R., Cost-effectiveness analysis of end-stage renal disease treatments, *Med Care*, 25: 25-34, 1987

21. Tousignant, P., Guttmann, R.D., and Hollomby, D.J., Transplantation and home hemodialysis: their cost-effectiveness, *J Chronic Dis*, 38: 589-601, 1985

22. Ludbrook, A., A cost-effectiveness analysis of the treatment of chronic renal failure, *Applied Economics*, 13: 337-350, 1981

23. Thompson, K., Cost comparison of in-center dialysis, home dialysis, and transplantation in the Nashville area, *Nephrology Nurse*, Nov/Dec: 24-25, 1980

24. Weydevelt, F.C., Bacquaert-Dufour, K., Benevent, D., Lavaud, S., Beaud, J., Allard, B., Riberi, P., and Dandavino, R., A cost-effectiveness analysis of continuous ambulatory peritoneal dialysis vs self-care in-center hemodialysis in France, *Dial Transplant*, 28: 70-74, 1999

25. Croxson, B.E. and Ashton, T., A cost effectiveness analysis of the treatment of end-stage renal failure, *N Z Med J,* 103: 171-174, 1990

26. Churchill, D., Taylor, D.W., and Keshaviah, P., Adequacy of dialysis and nutrition in continuous peritoneal dialysis: association with clinical outcomes, *J Am Soc Nephrol,* 7: 198-207, 1996

27. Charlson, M.E., Pompei, P., Ales, K.L., and MacKenzie, C.R., A new method of classifying prognostic comorbidity in longitudinal studies: development and validation, *J Chronic Dis*, 40: 373-383, 1987

28. Beddhu, S., Bruns, F.J., Saul, M., Seddon, P., and Zeidel, M.L., A simple comorbidity scale predicts clinical outcomes and costs in dialysis patients, *Am J Med,* 108: 609-613, 2000

29. Manns, B.J., Mortis, G., Taub, K., McLaughlin, K., Donaldson, C., and Ghali, W.A., The Southern Alberta Renal Program Database: A prototype for patient management and research initiatives, *Clinical Investigative Medicine,* 24 (4): 164-170, 2001

30. Canadian Institute for Health Information: Guidelines for Management Information Systems in Canadian Health Service Organizations in Ottawa, Canadian Institute for Health Information, 1999

31. McKillop, I., A Research Project to Examine the Costing Methodologies Recommended in the MIS Guidelines in Ottawa, Canadian Institute for Health Information, 1995, p 155

32. McKillop, I., Pink, G.H., and Johnson, L.M., The Financial Management of acute care in Canada: A review of funding, performance monitoring and reporting practices in Ottawa, Canadian Institute for Health Information, 2001, p 83

33. MacLeod, A., Grant, A., Donaldson, C., Khan, I., Campbell, M., Daly, C., Lawrence, P., Wallace, S., Vale, L., Cody, J., Fitzhugh, K., Montague, G., and Ritchie, C., Effectiveness and efficiency of methods of dialysis therapy for end- stage renal disease: systematic reviews, *Health Technol Assess,* 2: 1-166, 1998

34. Hirth, R.A., Held, P.J., Orzol, S.M., and Dor, A., Practice patterns, case mix, Medicare payment policy, and dialysis facility costs, *Health Serv Res,* 33: 1567-1592, 1999

35. Nassar, G.M. and Ayus, J.C., Infectious complications of the hemodialysis access, *Kidney Int*, 60: 1-13, 2001

36. NKF-K/DOQI: Clinical Practice Guidelines for Vascular Access: update 2000, *American Journal of Kidney Diseases*, 37: S137-181, 2001

Table 1 – Baseline characteristics of enrolled patients, overall and for patients treated with different dialytic modalities

Variable	All patients n = 166	In-center HD n = 88	Satellite HD n = 31	Home/Self Care HD n = 9	Peritoneal dialysis n = 38
Mean age [1], years (95% CI)	60.9 (58.5, 63.3)	61.8 (58.4, 65.3)	63.7 (58.4, 69.1)	55.6 (43.3, 67.9)	57.7 (52.6, 62.9)
Male sex (%) [1]	91 (54.8%)	55.7%	61.3%	44.4%	50.0%
Caucasian ethnicity [1] (%)	124 (74.7%)	76.1%	71.0%	88.9%	71.1%
Working (%)	28 (16.9%)	11.4%	12.9%	33.3%	29.0%
Income (%), n = 130 [2] respondents					
Under $10,000	26 (20.0%)	20.9%	9.5%	25.0%	23.5%
From $10,000 to $30,000	47 (36.2%)	38.8%	47.6%	37.5%	23.5%
Over $30,000	57 (43.9%)	40.3%	42.9%	37.5%	52.9%
Living arrangements, n = 157 [2] (%)					
Independent	97 (61.8%)	61.5%	65.5%	66.7%	58.3%
Require part-time home care	48 (30.6%)	28.9%	27.6%	33.3%	36.1%
Requires 24 hour / long-term care	12 (7.6%)	9.6%	6.9%	0.0%	5.6%
Months on dialysis [1], median (IQR)	38.5 (31.9, 45.0)	41.2 (31.9, 50.5)	28.8 (23.6, 34.1)	54.7 (11.4, 120.8)	36.2 (22.2, 50.1)
Charlson comorbidity index [1], Mean (95% CI)	4.2 (3.9, 4.5)	4.3 (3.9, 4.7)	3.8 (3.2, 4.5)	3.4 (2.5, 4.4)	4.3 (3.7, 5.0)
Low risk (≤ 3)	68 (41.0%)	38.6%	51.6%	44.4%	36.8%
Medium risk (4 - 5)	60 (36.1%)	36.4%	25.8%	55.6%	39.5%
High risk (≥ 6)	38 (22.9%)	25.0%	22.6%	0.0%	23.7%
Comorbid Conditions (%)					
Coronary heart disease	56 (33.7%)	34.1%	32.3%	11.1%	39.5%
Congestive heart failure	33 (19.9%)	25.0%	6.5%	11.1%	21.1%
Peripheral vascular dis.	42 (25.30%)	25.0%	19.4%	22.2%	31.6%
Previous stroke	29 (17.47%)	12.5%	32.3%	11.1%	18.4%
Lung disease	43 (25.90%)	27.3%	25.8%	11.1%	26.3%
Diabetes	50 (30.12%)	27.3%	19.4%	33.3%	44.7%
Baseline laboratory values, mean (95% CI)					
Hemoglobin (g/l)	118 (116, 120)	118 (116, 121)	117 (113, 120)	121 (113, 129)	117 (111, 124)
Albumin (g/l)	33.5 (32.9, 34.2)	34.4 (33.6, 35.1)	34.7 (33.6, 35.7)	34.7 (32.6, 36.7)	30.4 (28.8, 31.9)
Kt/V	1.8 (1.7, 1.9)	1.5 (1.5, 1.6)	1.6 (1.5, 1.6)	1.7 (1.5, 1.9)	2.5 (2.3, 2.7)

[1] $p < 0.05$ for comparison of dialytic modalities by one-way ANOVA
[2] 'n' is not equal to 166 due to missing data

Table 2 – Annual health care related costs per patient, by modality

Cost category	Peritoneal Dialysis	Hemodialysis		
	Continuous ambulatory peritoneal dialysis and Cyclic peritoneal Dialysis n = 38	Home/Self Care n = 9	Satellite n = 31	In-center n = 88
Outpatient dialysis costs, mean (median, 25-75 percentile) [1]	$21,741 (20,999, 20,949-22,533)	$21,408 (21,612, 19,514-23,302)	$34,964 (34,146, 33,822-34,723)	$38,703 (38,609, 38,109-39,124)
Inpatient costs, mean [2] (median, 25-75 percentile) [1]	$5,612 (0, 0-4,902)	$3,137 (0, 0-0)	$2,598 (0, 0-3,116)	$8,915 (0, 0-9,992)
Outpatient costs				
Clinic Visits, mean (median, 25-75 percentile) [1]	$78 (70, 47-93)	$60 (70, 23-70)	$49 (47, 23-93)	$62 (51, 36-89)
Emergency room, mean (median, 25-75 percentile) [1]	$510 (150, 0-494)	$313 (0, 0-141)	$228 (141, 0-366)	$297 (102, 0-505)
Day Surgery, mean (median, 25-75 percentile) [1]	$64 (0, 0-0)	$285 (0, 0-612)	$402 (0, 0-0)	$342 (0, 0-0)
Lab costs, mean (median, 25-75 percentile) [1]	$636 (428, 302-893)	$442 (417, 369-619)	$481 (373, 276-567)	$947 (760, 536-1,235)
Diagnostic Imaging, mean (median, 25-75 percentile) [1]	$1,096 (140, 0-939)	$2,467 (610, 290-3,807)	$1,766 (752, 140-2,987)	$2,470 (865, 144-3,143)
Eprex™, mean (median, 25-75 percentile) [1]	$5,879 (5,626, 1,631-10,659)	$7,307 (7,106, 3,553-9,786)	$6,250 (3,553, 0-10,659)	$7,765 (5,854, 3,553-10,659)
Venofer™, Mean (median, 25-75 percentile) [1]	$160 (0, 0-403)	$586 (806, 446-892)	$647 (892, 0-892)	$553 (892, 0-892)
Medications [3], mean (median, 25-75 percentile) [1]	$4,265 (4,042, 2,117-5,246)	$3,968 (3,599, 2,537-3,702)	$3,793 (3,556, 2,695-4,910)	$4,252 (3,787, 2,549-5,427)
Physician Billing, mean (median, 25-75 percentile) [1]	$2,753 (2,247, 2,247-3,723)	$4,171 (4,171, 4,171-4,171)	$9,804 (9,110, 9,110-9,747)	$10,143 (9,110, 9,110-10,748)
Total expenses, mean (95% CI)	**$43,193 (37,723, 48,663)**	**$44,143 (31,394, 56,892)**	**$60,983 (57,308, 64,658)**	**$74,316 [4] (69,137, 79495)**

[1] Reported as median with 25-75 percentile since distribution not normal
[2] Including nursing, medications, labs, diagnosis, support staff, surgery and supplies
[3] Excluding Eprex and Venofer.
[4] $p < 0.001$ comparing the four modalities using one-way ANOVA

Table 3 – Monthly outpatient dialysis costs per patient, by modality

	Peritoneal Dialysis		Hemodialysis			
	Continuous Ambulatory Peritoneal Dialysis	Cyclic Peritoneal Dialysis	Self Care Hemodialysis	Home Hemodialysis	Satellite Hemodialysis	In-Center Hemodialysis
Nursing [1], Mean (Median, 25-75 percentile) [2]	$200 (166, 127-245)	$148 (127, 85-226)	$464 (464, 464-464)	$339 (329, 283-419)	$1,489 (1,420, 1,393-1,469)	$1,686 (1,678, 1,636-1,721)
Supplies	$1,250 [3]	$1,680 [3]	$611	$611	$611	$611
Machines	N/A	N/A	$176	$212	$139	$139
Water	N/A	N/A	$45	$352	$90	$45
Overhead [4]	$290	$366	$259	$303	$582	$744
Total	**$1,740**	**$2,194**	**$1,555**	**$1,817**	**$2,911**	**$3,225** [5]

[1] including technician time
[2] reported as median with 25-75 percentile since distribution not normal
[3] For cont, the average patient used four "2.5 litre" dianeal exchanges/day; for cyclic peritoneal dialysis, the average patient cycled ten litres of Dianeal at night, with one 2 litre Dianeal daytime exchange.
[4] Thirty percent for in-center; twenty-five percent for satellite and self-care; twenty percent for home hemodialysis and peritoneal dialysis.
[5] $p < 0.001$ for comparison of six dialytic modalities using one-way ANOVA

Table 4 – Annual dialysis access-related diagnostic imaging, surgical and inpatient costs.

Access Type	Mean number of access-related interventional radiology visits [1] per patient per year	Mean access-related radiology cost per patient per year (median, 25-75 percentile) [2]	Mean number of access-related surgical visits per patient per year [3]	Mean access-related surgical costs per patient per year (median, 25-75 percentile) [2]	Mean number of hospital days for access-related problems per patient per year [4]	Mean cost for access-related hospital admissions per patient per year (median, 25-75 percentile) [2]	Total mean costs for access-related health care per patient per year (median, 25-75 percentile) [2]
Hemodialysis [5]							
Permanent catheter (n = 15)	0.60	$2,617 (1,464, 0-2,563)	0.20	$123 (0, 0-0)	0.27	$437 (0, 0-0)	$3,177 (2,144, 0-3,156)
Synthetic graft (n = 36)	0.72	$2,925 (2,396, 0-4,524)	1.08	$678 (0, 0-1,071)	1.22	$1,247 (0, 0-0)	$4,850 (3,499, 590-6,725)
Arteriovenous fistula (n = 72)	0.32	$502 (0, 0-523)	0.10	$84 (0, 0-0)	0	$0	$586 (0, 0-732) [6]
Peritoneal Dialysis							
Peritoneal dialysis catheter (n = 38)	0.25	$240 (0, 0-0)	0.11	$62 (0, 0-0)	0.44	$259 (0, 0-0)	$562 (0, 0-0)

[1] includes vascular line placement, fistulograms, and access-related angioplasties
[2] reported as median with 25-75 percentile since distribution not normal
[3] includes access declotting / revision and creation of new vascular access done as a day care patient
[4] includes admission for line-associated bacteremia, other complications related to vascular access (post-surgical complications), and admissions for peritonitis
[5] patients who started the study with a temporary catheter (n = 5) who had active plans to create a permanent vascular access were excluded from this analysis
[6] $p < 0.001$ comparing the three hemodialysis access groups using the Kruskal-Wallis test

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